SECTION 2
COSTS OF REGULATION FOR ARCHITECTURAL COATING PRODUCERS

This section estimates the costs to comply with the architectural coatings regulation and examines the economic impacts of these costs as they are distributed across producers and consumers of the regulated products through market processes. The analysis in this section focuses on the(primary)impacts defined within the architectural coatings product markets. An assessment of impacts on users of traffic coatings addresses selected secondary impacts in other sectors of the economy. That analysis is presented in Section 4.

2.1 BACKGROUND

The EPA plans to control VOC emissions from architectural coatings using a combined regulatory approach: (1) product-specific VOC content limits, (2) an option for producers of products that exceed the content limits to pay a fee on the VOC content in excess of the limit, and (3) a phased tonnage exemption that allows each manufacturer the option to claim as exempt a limited number of products that result in a specified amount of emissions annually. Using reformulation cost estimates and an exceedance fee rate, the Agency analyzed the potential impacts of the regulation, first using static analyses of regulatory response options and second using a dynamic market analysis that estimates changes in prices, quantities, and social welfare.

2.2 OVERVIEW OF RESPONSE OPTIONS

The regulation to reduce the VOC content of architectural coatings will affect both production decisions for the suppliers of the coatings (through its impact on costs and revenues) and consumption decisions for the demanders (through its impact on product prices). Before developing a formal economic model to analyze these regulations, the Agency needed to characterize the scope of responses available to producers and consumers.

2.2.1 Supply

The EPA is proposing a set of limits for the VOC content in specific product categories to be met in 1999. Firms that produce products exceeding the VOC limits essentially have three compliance options:

- reformulate the products so that they comply with the standard,
- pay a fee on the excess VOC content over the standard, or
- remove the product from the market.

Each producer also may exempt a small quantity of product from compliance.

This analysis assumes that firms will choose the option that maximizes their net benefits, as measured by the expected (discounted) value of the profits generated under each option. Although decisions in the short-run may differ from decisions made to maximize net benefits in the long run, this analysis primarily considers the long-run decisions and their impact on the architectural coatings markets. Uncertainties pertaining to short-run decisions are discussed in Section 2.7.

The first option for producers to comply with the rule is to reformulate products that exceed the specified VOC content. Product reformulation often involves an investment in research and development (R&D) to develop a compliant product. The extent of the reformulation necessary to bring a product into compliance can vary from product to product. In some cases, compliance can be achieved for a particular product without large R&D investments because the product is similar enough to an existing formula or another product undergoing reformulation. A major reformulation, as is discussed throughout this analysis, typically requires a significant resource and time commitment. The process can take several years and is divided into a number of different stages. Figure 2-1 identifies the basic reformulation stages for a prototype architectural paint (other coatings such as varnishes may have fewer stages).[51] The firm may subsequently need to alter its capital equipment to produce the reformulated product, but these physical capital adjustments are usually small compared to developing the intellectual capital to devise the new formula.

The analysis that follows assumes that manufacturers bear the full cost of each reformulation. Since the VOC content limits in the rule reflect available resin technologies, it is likely that the costs associated with reformulation will at least partially be shared by resin manufacturers/suppliers. In that regard, the direct impacts on manufacturers will be overstated in the analysis. This and other potential upward and downward biases in the cost estimation methodology are addressed later in this section.

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Figure 2-1. Basic stages of architectural coating reformulation (prototype firm and product).

Source: AIM Coatings Regulatory Negotiation Committee meeting. July 28-30, 1993, Washington, DC. Meeting Summary.

2.2.2 Demand

The regulation can be expected to induce changes in the prices of the affected products. Product consumers may alter their selection of coatings based on the relative prices of coating products and on the relative prices of coating versus noncoating alternatives. For example, consumers might opt for a waterborne coating rather than its solventborne alternative if the regulation-induced change in prices increases the relative price of the solventborne product. Moreover, a potential user of a high-VOC coating product facing reformulation may even opt for a noncoating alternative if the price rises too much.

The reformulated products can also possess different characteristics that affect their demand. For instance, VOC content reduction in a typically high-VOC product may change consumers' perceptions of the product's performance, durability, and ease of application. The lower VOC content may also work as a signaling device for the "green" consumer in pursuit of products deemed more friendly to the environment.[a] These factors collectively affect the benefit consumers derive from using the product and thus their willingness to pay for the reformulated product versus other product alternatives.

2.3 COST ANALYSIS

This section evaluates the costs imposed on manufacturers to reformulate noncompliant products, describes and quantifies the exceedance fee provision, and incorporates the option of withdrawing products from the market into the decision process.

2.3.1 Costs of Reformulation

Of the compliance options referenced above, reformulation of products that have a VOC content exceeding the category limit in the TOS (see Table 2-1) is the most significant both in terms of potential cost and emission reductions. The economic analysis begins by estimating the national cost of the regulation in the absence of other compliance options (fee, withdrawal) and ignoring market responses. This will provide an upper-bound estimate for the true national costs of the regulation. The national estimate will be modified (reduced) as the other compliance options and market behavior are explicitly considered below.

[a]Some manufacturers currently produce zero-VOC-content coatings that are marketed as "clean air" coatings.

TABLE 2-1. TABLE OF STANDARDS[a]

Architectural Coating	VOC Content Limit (g/L)
Antenna coatings	500
Antifouling coatings	450
Antigraffiti coatings	600
Bituminous coatings and mastics	500
Bond breakers	600
Chalkboard resurfacers	450
Concrete curing compounds	350
Concrete protective coatings	400
Dry fog coatings	400
Extreme high-durability coatings	800
Fire-retardant/resistive coatings	
Clear	850
Opaque	450
Flat coatings, N.O.S.	
Exterior	250
Interior	250
Floor coatings	400
Flow coatings	650
Form release compounds	450
Graphic arts coatings (sign paints)	500
Heat reactive coatings	420
High-temperature coatings	650
Impacted immersion coatings	780
Industrial maintenance coatings	450
Lacquers (including lacquer sanding sealers)	680
Magnesite cement coatings	600
Mastic texture coatings	300
Metallic pigmented coatings	500
Multicolor coatings	580
Nonferrous ornamental metal lacquers	870

(continued)

TABLE 2-1. TABLE OF STANDARDS[a] (CONTINUED)

Architectural Coating	VOC Content Limit (g/L)
Nonflat coatings, N.O.S.	
Exterior	380
Interior	380
Nuclear power plant coatings	450
Pretreatment wash primers	780
Primers and undercoaters, N.O.S.	350
Quick dry coatings	
Enamels	450
Primers, sealers, and undercoaters	450
Repair and maintenance thermoplastic coatings	650
Roof coatings	250
Rust preventive coatings	400
Sanding sealers	550
Sealers	400
Shellacs	
Clear	650
Opaque	550
Stains	
Opaque	350
Clear and semitransparent	550
Waterborne low solids	120
Swimming pool coatings	600
Thermoplastic rubber coatings and mastics	550
Traffic marking paints	150
Varnishes	450
Waterproofing sealers and treatments	
Clear	600
Opaque	400
Wood preservatives	
Below ground	550
Clear and semitransparent	550
Opaque	350

N.O.S. = Not otherwise specified.

[a] The final Table of Standards included in the regulation differs slightly from this list. See Section 7 for a discussion.

The method for estimating the national costs of the regulation under this scenario is to:

1. Estimate reformulation cost per product

2. Estimate the total number of products nationwide facing reformulation

3. Multiply the cost per product times the number of reformulations

These steps are now presented in sequence.

2.3.1.1 Product-Level Reformulation Cost Estimates.

Developing a new formula for an architectural coating involves altering the mix of the four coating components: resins, solvents, pigments, and additives. For solventborne products, a new formula might increase the ratio of solids (resins) to solvents to reduce the solvent's contribution to VOC emissions.

Reformulation is a one-time investment to develop a formula that complies with the VOC requirement. This generally involves applying R&D effort to develop and test the new formula. Various other expenses (e.g., administrative and marketing) are incurred to get the reformulated product to market; however, for the purposes of this report, all relevant costs are collectively referred to as "reformulation" costs.

The level of effort for reformulation varies across products, depending on the product's characteristics and the difference between a product's VOC content and the standard. For the analysis at proposal, EPA used information provided at a regulatory negotiation meeting on July 28, 1993 on the cost of developing a new product formula to meet a standard that was more stringent than that which was proposed.[52] Because other data were not available to gauge the reasonableness of this estimate, the EPA solicited input during the public comment period for this rule to determine the appropriateness of the value used at proposal. Appendix B provides a summary of the information received. These data show that the value used at proposal was considerably above estimates provided by commenters. Thus, the value used for this analysis is revised to reflect both the initial estimate from the regulatory negotiation and the subsequent estimates provided during the public comment period. Not enough information was provided in these comments, however, to estimate separate costs for each specific product category; therefore, the average of the estimates provided is used as the cost of reformulation for all products subject to the regulation. That average cost is $87,000 per product and will be used throughout this analysis to estimate the economic impacts, unless otherwise indicated.[b]

Cost annualization. Several of the comments received during the public comment period indicate a concern that the cost estimate used at proposal was too low. However, the lump-sum cost estimate used at proposal ($250,000) was considerably higher than the estimates provided in the public comments. Therefore, the concern appears to be centered around the annualized cost estimate used at proposal ($17,772 per year). In many cases, commenters appeared to be comparing the annualized cost used in the proposal to their estimate of lump-sum costs to reformulate. The purpose of annualizing costs and the methods for doing so in this analysis are presented below.

Reformulation is a one-time effort to develop a new formula. But the useful life of the formula goes beyond the year in which reformulation occurs. In this regard, it is

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[b]Please note that because the base year for all information to develop the regulation (i.e., product inventories, VOC content limits, estimated emission reductions, etc.) is 1991, all costs and economic impacts presented in the analysis are expressed in 1991 dollars unless otherwise indicated. All cost and economic impact measures are transformed to present dollars in Section 7 for external reporting purposes.

much like any other capital investment (in this case, "knowledge" capital), so the cost must be amortized over the useful life of the investment.

The standard formula for annualizing a lump sum investment cost is

$$a = I \bullet [i(1+i)^n / ((1+i)^n - 1)]$$

where a equals the annualized amount, I is the initial lump sum investment cost, i is the interest (discount) rate, and n is the useful life of the investment. As indicated above, the revised value for the lump-sum investment used throughout this analysis is $87,000 per product. The discount rate is 7 percent, which is the rate recommended by the Office of Management and Budget (OMB) for cost-benefit analysis of federal regulations.[53] Determining the number of years to use in the annualization formula, n, requires considering the "useful life" of the knowledge developed in reformulation. More specifically, how long do the benefits of the current investment accrue? Reformulation allows the firm to continue to sell the current product (at a lower VOC content), rather than remove the product from the market. Therefore, the time stream of the benefits to the firm is at least as long as the reformulated product will remain on the market (i.e., the product life). This is a complicated issue. A particular version (formula) of a product may remain on the market for many years, then be reformulated to add different product attributes and kept in the market as a new and improved version of the old product. This product reformulation rotation may recur continuously into the future. If so, what is the best way to estimate the useful life of the VOC reduction technology induced by the regulation?

Two assumptions were considered to capture the range of possibilities for the useful life of the reformulation investment.

1. The low-VOC technology developed for the new formula is applicable only to that formula and cannot be transferred to future adjustments of the product.

2. The low-VOC technology developed for the new formula is applicable to that formula and is transferrable to all future versions of the product forever.

Case 1: In the first case, if the reformulated product is expected to remain on the market for a certain number of years (T), then the useful life of the VOC reduction investment is T years and the initial cost should be annualized accordingly (n=T). Moreover, if the current product is simply replaced T years hence by a reformulated version of the product, it is assumed that the VOC reduction technology developed for the current product is nontransferrable to the next product. Thus, an entirely new investment in VOC reduction technology T years in the future (the time of the next reformulation) is assumed necessary. This defines the most pessimistic (i.e., shortest) estimate for the useful life of the current VOC reduction investment. Because shortening the useful life of an investment reduces the amortization period, it also raises the annualized cost of compliance, therefore providing the upper-bound estimate for this analysis.

Estimating the cost under the first assumption requires determining an appropriate product life for a typical architectural product. Attempts to obtain this information from secondary data and industry sources proved unsuccessful since a “typical” product was too difficult to define. A life of T=8 years was assumed to be a reasonable, if conservative, base case estimate of a single product life cycle. Thus a_1 is the annualized reformulation cost per product for case 1 (high estimate), with an $87,000 reformulation investment, a useful life of 8 years, and discounted at 7 percent, which is computed as follows:

$$a_1 = \$87,000\ [0.07(1.07)^8 / ((1.07)^8 - 1)] = \$14,573.$$

Case 2: In the second case, the low-VOC technology developed for the regulation applies to all current and future versions of the reformulated product. In other words, once the VOC technology is developed for the new formula, it does not need to be re-developed in the future, even if the product is modified in the future to add new attributes. As a result, the useful life is the length of time the firm expects to remain in the product market. In the extreme case, the firm has no plans to remove the product from the market and the useful life is essentially infinite. Under this assumption, the cost is amortized in perpetuity to make it comparable with the benefits of the VOC technology. Thus, the cost annualization formula yields a_2, the estimate of reformulation cost per product:

$$a_2 = \$87,000 \bullet 0.07 = \$6,090.$$

Because a firm may not expect to remain in the market forever and/or the current VOC reduction technology may not transfer perfectly to all future versions of the current product, the assumption for case 2 can be viewed as a lower-bound estimate of annualized costs.

However, under an alternative interpretation, the costs may be lower still. Suppose a company, in the absence of the VOC standards, would routinely reformulate its product every few years. Then, the VOC regulation can be viewed not as forcing firms to reformulate the product; rather, it forces them to reformulate their products sooner than they otherwise would. Thus, the one-time cost to the firm is the present value of accelerating the series of costs that would occur (later) without the regulation. This cost will, in general, be less than the lump-sum cost of reformulation referenced above; therefore, the annualized measures would be lower as well. This is demonstrated by numerical example in Appendix C.

To summarize, data from the regulatory negotiation and public comment periods were used to provide EPA's best estimate of the cost of reformulation. The average reformulation cost estimate is $87,000 per product. This is a one-time cost that must be annualized for policy analysis. The annualized cost estimate depends on the assumption about the new formula's useful life. Under a useful life estimate of 8 years, the annualized cost per product is $14,573. As indicated, a number of assumptions can be justified on theoretical and empirical grounds that would reduce this estimate. For example, the useful life of the reformulation investment may well exceed 8 years. Also, reformulations occur as a normal business practice and the cost of reformulation for VOC content may not be entirely incremental. However, the $14,573 estimate is the maintained value throughout the analysis, except where otherwise indicated, thereby providing a conservatively high cost estimate.

<u>South Coast Air Quality Management District (SCAQMD) study</u>. As a point of comparison, estimates of the cost of architectural coatings reformulation are provided in a study conducted for the SCAQMD to address economic impacts of VOC content regulations in California.[54] This study identified costs associated with product reformulation and temporary and permanent product sales losses. Reformulation costs varied depending on the extent of the reformulation necessary. Most of the small firms surveyed indicated that they did not have full-time R&D employees. Costs for additional research and

development due to the regulation ranged from $1,000 to $5,000 annually for firms with few products affected by the California rule and more than $50,000 for firms with many affected products and little or no research staff.

The SCAQMD study also identified other compliance costs not related to R&D. Rough estimates of the cost of equipment adjustments necessary to accommodate reformulation ranged from $5,000 to $35,000 per firm. Costs attributed to temporarily or permanently discontinued products ranged from zero to $3,000 for firms with few affected products to more than $75,000 for firms with many affected products. Per-product estimates were not presented. Employment changes for the surveyed firms in the SCAQMD study were expected to be minimal, affecting only the possible addition of R&D chemists.

Because the timing, number of reformulated products, cost components, and regulatory structure associated with each SCAQMD cost estimate are not apparent from the report, they cannot be combined with the estimates presented above in any meaningful fashion to improve the estimate of regulatory costs.

2.3.1.2 National Reformulation Costs. The analysis of national reformulation costs begins with the recognition that the population of regulated products can be broken into two groups: those included in the emissions survey and those omitted from the survey. The methods used to estimate costs for each group are presented in turn.

Survey population. In this section, aggregate reformulation costs are for the products reported in the Architectural and Industrial Maintenance Surface Coatings VOC Emissions Inventory Survey (the survey).[55] The survey population represents roughly three-fourths of total industry output. The analysis is then extended to the industry level to calculate a national estimate.

To estimate reformulation costs for the entire survey population, the number of architectural products that will need reformulation to comply with the standards is determined. This number depends on the number of architectural products with a VOC content exceeding the standards for the respective product categories.

The survey reports the number of products, sales volume, and average VOC content for specific VOC content ranges (e.g., 0 to 50 g/L, 51 to 100 g/L, 101 to 150 g/L) within specific product groups (e.g., exterior flat waterborne, exterior flat solventborne, interior flat waterborne). Knowing the limits imposed by the TOS, the number, volume, and average VOC content of products over the limit can be derived using the survey data. These data can be used to generate estimates of the expected cost of reformulating products subject to the TOS, as well as the associated reduction in emissions accomplished by the reformulations.

Nonsurvey population. By definition, characterizing the population of nonsurveyed products introduces further uncertainty into the analysis. To estimate the number of nonsurveyed products facing reformulation, one must use product information from the survey population and apply it to the nonsurvey population subject to some assumption about the correspondence between the two populations. The economic analysis presented at proposal performed this task subject to the assumption that the overall survey population was representative of the nonsurvey population. Further scrutiny suggested a more appropriate assumption would be that the nonsurvey population was more accurately represented by the small company component of the survey population. A supplemental analysis in the appendix of the proposal analysis addressed this issue and indicated that national cost of the regulation is higher when the assumption that all nonsurveyed products are produced by small companies is applied. That assumption is maintained and further refined to generate cost estimates for the nonsurvey population in this analysis, as described below.

For each of the 13 defined market segments in the architectural coatings industry, data were available on total market volume (in liters) derived from the Census of Manufactures data for the baseline year (1991) and the total volume of surveyed products for that category. From that data the total volume omitted from the survey (i.e., volume produced by the nonsurvey population) can be computed:

$$\text{Nonsurveyed volume} = \text{Market volume} - \text{Surveyed volume} \quad (2.1)$$

If the average size of nonsurveyed products is known, the number of nonsurveyed products can be estimated as follows:

$$\text{Nonsurveyed products} = \text{Nonsurveyed Volume} / \text{Average volume of an nonsurveyed product} \quad (2.2)$$

If the proportion of nonsurveyed products needing reformulation is known, then the number of nonsurveyed product reformulations can be computed:

$$\text{Nonsurveyed product reformulations} = \text{Nonsurveyed products} \bullet \text{Proportion of nonsurveyed products needing reformulation} \quad (2.3)$$

and the corresponding reformulation costs are then

$$\text{Cost of nonsurveyed product reformulations} = \text{Nonsurveyed product reformulations} \bullet \text{Reformulation cost per product} \quad (2.4)$$

Because no specific data on nonsurveyed products were available for this analysis, the average product volume needed in Eq. (2.2) and the reformulated product proportions needed in Eq. (2.3) are not known. However, the information from the surveyed products can be used to impute values for the nonsurveyed products. One option is to assume that nonsurveyed products are the same average size and have the same rate of product reformulation as surveyed products. However, as indicated above, the survey population is not necessarily representative of the nonsurvey population, because the former includes mostly large companies and the latter mostly small companies. To more appropriately capture the differences between the nonsurvey population and the survey population, the following assumptions are proposed:

(1) Let the average size of nonsurveyed products in each market segment equal the average size of **small** company products reported for that market segment in the survey data.

(2) Let the nonsurveyed product reformulation rate in each market segment equal the reformulation rate for **small** company products reported for that market segment in the survey data.

The effect of assumption (1) is to increase the number of nonsurveyed products and thereby increase the number of nonsurveyed product reformulations and associated costs, relative to the alternative assumption that nonsurveyed products are produced by both large and small companies. Assumption (2) adjusts the estimates based on market segment-specific reformulation rates, which is greater on average for small companies. The combined effect of these two assumptions is to raise the cost of the regulation relative to the alternative assumption.

National estimate. Typically during the development of an air pollution regulation, an engineering analysis identifies the pollution control equipment required to comply with the rule and estimates the total installed capital cost in a memorandum to the public docket or as a section of the rule's Background Information Document (BID). The economic analysis typically uses this information to amortize costs on an annual basis and perform a market analysis. For the architectural rule, the control cost estimates are highly dependent on decisions made by the regulated producers in a market setting to either reformulate, pay an exceedance fee, or remove the over-limit product from the market. With the market emphasis, all costs were expressed in annual terms in the economic analysis presented at proposal. EPA received public comments suggesting that an estimate of total initial reformulation cost (the analog to total installed capital cost) would also be informative. This cost is computed and presented below, along with the standard annual cost estimates.

The national reformulation costs can then be estimated as follows:

$$\begin{aligned}&\text{National reformulation cost} =\\ &\quad \text{Cost of surveyed product reformulations} +\\ &\quad \text{Cost of nonsurveyed product reformulations} \qquad (2.5)\end{aligned}$$

Table 2-2 presents the results of the analysis for the TOS.[56] The first row of Table 2-2 reports reformulation costs and emissions reduction summed across all surveyed products. A total of 1,730 products from the survey exceed the limits that manufacturers and importers will be subject to, which is 36 percent of the total number of products in the survey

TABLE 2-2. NATIONAL COSTS: REFORMULATION-ONLY SCENARIO

Population	Number of Products Over Limit	Estimated Reformulations[a]	Initial Lump-Sum Cost[b] ($1991)	Annualized Cost of Reformulation ($1991)	
				Low[c]	High[d]
Surveyed products	1,730	1,153	$100,282,029	$7,019,742	$16,797,240
Nonsurveyed products	1,759	1,193	$103,760,202	$7,263,214	$17,379,834
Total	3,519	2,345	$204,042,231	$14,282,956	$34,177,074

Totals subject to rounding error.
NA = not applicable
[a] Based on the assumption that one-third of products over the limit do not need a major reformulation (see text).
[b] Based on an initial investment of $87,000 cost per product.
[c] Based on an annualized value of $6,090 cost per product.
[d] Based on an annualized value of $14,573 cost per product.

Source: Industry Insights. Architectural and Industrial Maintenance Surface Coatings VOC Emissions Inventory Survey. Prepared for the National Paint and Coatings Association in cooperation with the AIM Regulatory Negotiation Industry Caucus. Final Draft Report. 1993.

(4,846).[c] A presentation to the Regulatory Negotiation Committee indicated that roughly one in three products that exceeds the limits would not need a reformulation, primarily because the product lines are similar to others that will be reformulated. Thus, the costs are assessed for the remaining two-thirds of products over the limit to compute the aggregate cost estimate. After reducing the number of products, the estimated number of reformulations for the survey population is 1,153, yielding a range for an aggregate cost of reformulation of $7.0 to $16.8 million dollars (1991 dollars), depending on which useful life assumption is used to annualize the lump-sum value.

Nationally, about 2,345 products are subject to reformulation. The initial lump-sum cost to reformulate these products (at $87,000 per product) is just over $200 million. Depending on the annualized cost per product estimate used, annualized costs range from about $14 to $34 million per year. Again, these estimates overstate the expected cost of the regulation because they do not account for producers' best response (i.e., their lowest cost option) to the regulation. The next section discusses the part of the analysis that accounts for these actions.

2.3.2 Exceedance Fee Provision

Architectural coatings producers have the alternative of paying a fee per unit of output for products that exceed the limit. The fee will be computed as follows:

$$\text{fee} = (\text{actual VOC content} - \text{VOC limit}) \bullet \text{fee rate.} \quad (2.6)$$

[c]The actual survey total number of products is 4,920. However, throughout Section 2 of this report 4,846 is used as the total number (and the corresponding quantity and emissions) because product-level data were unavailable for 74 products in the survey.

VOC content is measured in grams per liter (less water and exempt compounds), and the fee rate is paid on the grams per liter in excess of the limit. The fee rate is $0.0024 per excess gram per liter with annual adjustments based on the gross domestic product (GDP) price deflator. Total fee payment per product simply equals the per-liter fee times total liters of production.

In this step of the analysis, the premise is that architectural coatings producers will choose the less costly of the reformulation and exceedance fee options as a compliance strategy. The choice is based largely on two product-specific factors: quantity of output produced and the "excess" VOC per unit.

The diagram in Figure 2-2 helps explain the effect that output quantity has on the choice between reformulating the product and paying an exceedance fee. The vertical axis represents the cost per liter of compliance and the horizontal axis measures product volume in liters annually. Since the cost of reformulation is a fixed cost (i.e., it is independent of the level of output), the average reformulation cost per liter of output falls as output levels increase. This situation is represented by the downward-sloping line in Figure 2-2. However, the exceedance fee per unit of output is constant with respect to the output levels. Let F be the exceedance fee per liter of output; the flat line extending from F on the vertical axis indicates that the fee rate is constant. For the purposes of this discussion, we ignore the role of fixed recordkeeping costs under the fee option. These costs are included in the empirical analysis that follows. In Figure 2-2, for all output levels less than Q^T the average cost of reformulation is higher than the per-unit fee, and for all output levels greater than Q^T, the average cost is below

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Figure 2-2. Fee versus reformulation.

the fee. This relationship indicates that the fee is the less costly alternative when output is less than Q^T and reformulation is the less costly alternative when output is greater than Q^T. Thus small volume producers are more likely to choose the fee, all else equal. As Figure 2-2 illustrates, the existence of a fee places an upper limit on the per-liter costs of complying with the regulation: $F \bullet Q$.

Figure 2-2 also illustrates the effect of different fee rates on the "threshold point" of quantity, below which the fee is the preferred option. If the fee were F′ instead of F, reflecting either a higher assessment rate per Mg of emissions or a higher amount of excess VOC per unit, the threshold point would be lower. Thus, for higher excess VOC categories and for higher fee rates, fewer producers would probably select the fee option, all else equal. Because the fee will be more cost-effective only for lower-volume products and lower excess-VOC categories, allowing the fee option should have a relatively small impact on variation from the aggregate emission reduction targets as long as the fee assessment rate is not set at an extremely low level.

2.3.3 Product Withdrawal

Up to this point, the analysis has focused on firms responding to the regulation by choosing the less costly alternative between reformulation and the fee regulatory response. However, this view of a producer's likely response is incomplete because the cost of the regulatory response must be weighed against the benefits of the action to the firm. Here the analysis equates regulatory compliance with the decision to pay the costs and remain in the market. Thus, the benefits of the compliance action are the net returns (revenues minus variable costs) obtained from continuing to produce the product. The net payoff of compliance for a particular architectural coating exceeding the limit can be expressed as follows:

$$B^R = P \bullet q - c(q) - r^*. \qquad (2.7)$$

To ease the notational burden, all terms are expressed in their annualized form: P is product price, q is annual output, c(q) is the product cost function (without regulation) with respect to annual output, and r* is the annualized cost of the least-cost option among regulatory responses (i.e., reformulation or fee). In other words, r* gives the cost of the solution to the least-cost decision discussed in the previous section.

The firm is assumed to select an output level (q*) that maximizes profits (B^{R^*}). In a competitive market, this is the point at which the marginal cost of production equals the market price. However, the firm will only operate in this market if it can cover its production costs and compliance costs; that is, if the following condition is met:

$$B^{R*}\ (q^{R*}\ r^*) \geq 0. \tag{2.8}$$

If the condition in Eq. (2.8) is not met, then the firm's best response is to withdraw the product, produce no output ($q^{R*}=0$), and generate zero profits for the product ($B^{R*}=0$). In this regard, product withdrawal would be the firm's least cost option, because the alternative implies they lose money by remaining in the market.

2.3.4 "Best-Response" Analysis

The analysis presented here determines which option (fee, reformulation, or withdrawal) is the best response for specific products within a certain VOC content range from the survey.

For the purpose of this analysis, a product stratum is defined as all products existing in a specific VOC content range for a specific product category. An example of a stratum would be all exterior flat waterborne products in the 101 to 150 g/L VOC content range. For the TOS, all strata in the survey were examined to determine those that exceed limits for their respective product categories. As indicated above, the survey includes data on the number of products, sales volume, and baseline VOC emissions for each stratum. These data were used to compute average sales volume per product for all strata exceeding the TOS limits. These average volume estimates formed the basis for computing exceedance fee costs and product-level profits.

An example of a best response determination is as follows:

(Best-Response Example)

Suppose the average sales volume per product for one stratum is 100,000 L/yr. To determine the exceedance fee for each stratum, the midpoint of the VOC content range was used as an estimate of average VOC for the stratum. This measure was used to compute excess VOC content because it is consistent with the regulatory definition of VOC content (grams per liter less water and exempt compounds) and is available for each stratum.

First the fee rate was adjusted to 1991 dollars by multiplying the fee rate (in 1996 dollars) of 0.0028/g by the ratio 1991/1996 of GDP price deflators. The resulting fee rate is 0.0024/g. Suppose the midpoint of the stratum is 150 g/L above the limit. The associated fee per unit would be 150 • $0.0024 = $0.36/L. The total exceedance fee payment for the product is ($0.36/liter) • 100,000 liters = $36,000 per year. Fixed recordkeeping costs must also be incurred for products subject to the fee. Fee-related recordkeeping costs were estimated to be $590 per product per year.[57] Adding these numbers together, the compliance cost under the fee option is $36,590 per year. This exceeds the annualized cost of reformulation ($14,570 per year). Under these conditions, it is assumed that products in this stratum would reformulate rather than pay the exceedance fee.[d] This decision would be reversed if, for instance, the stratum exceedance were 50 g/L, in which case the fee payments would be $12,000, which, adding in the fixed cost of $590, is below the reformulation cost per product.

To simulate the reformulation/fee/withdrawal decision, per-unit profits were estimated to compare with unit costs for each stratum and computed as follows:

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[d]By conducting the fee-versus-reformulation decision at the stratum level, and basing the decision on average cost and fee for each stratum, it is implied that all products within the stratum are identical to the mean values. In reality, there will be some variation around the mean so that some producers may find one alternative less costly while others find the other alternative less costly. This analysis is unable to capture this heterogeneity with the available data, but presumably these effects are smoothed out as the analysis compares means across the hundreds of strata in the survey.

$$B^u = P \cdot m \tag{2.9}$$

where P is the output price and m is the profit margin. For each product category analyzed, the average market price for the market in which the product category belongs was used (see Table 2-3).[58,59] The model derives the returns-to-fixed-factors (RFF) profit margin as follows:

$$m = 1 - (\text{variable cost/revenues}). \tag{2.10}$$

The ratio of variable cost to revenue can be computed using values provided by the NPCA. The variable cost component in the numerator includes the cost of goods sold plus variable selling and storage costs. These variable costs comprise 81.7 percent of revenues for the mean producer surveyed by NPCA, so the estimate of the RFF profit margin is 0.183.

These average reformulation cost per liter and profit calculations were performed for each stratum above the TOS limits to determine the relative frequency of reformulation/fee/withdrawal selections and their impact on compliance costs. These analyses were performed directly for the survey population, with the results used to impute values for the nonsurvey population. Results are presented for the survey population in Table 2-4.

Under the chosen fee rate of $0.0024 (1991 dollars), the fee is the preferred alternative for 409 (35.5 percent) of the

TABLE 2-3. ARCHITECTURAL COATINGS MARKET SEGMENTS BASELINE DATA FOR 1991

No.	Market Segment[a]	Quantity Produced (kL)[b]	Value ($$10^3$)	Average Price ($/L)
1	Exterior & high performance solventborne coatings	162,937	540,511	3.32
2	Exterior & high performance waterborne coatings	468,345	1,046,383	2.23
3	Interior solventborne coatings	94,935	302,264	3.18
4	Interior waterborne coatings	833,434	1,747,341	2.10
5	Solventborne primers & undercoaters	61,298	171,583	2.80
6	Waterborne primers & undercoaters	75,212	160,960	2.14
7	Solventborne clear coatings, sealers, & stains	134,678	412,743	3.06
8	Waterborne clear coatings & stains	120,738	266,174	2.20
9	Architectural lacquers	40,011	83,320	2.08
10	Wood preservatives[c]	27,449	493,965	1.45
11	Traffic marking paints	91,067	132,358	1.45
12	Special purpose coatings	34,568	141,633	4.10
13	Industrial maintenance coatings	231,261	797,006	3.45
	Totals/averages	2,375,933	6,296,241	2.65

[a] See Appendix A for an explanation of products included in each market segment.

[b] The quantities and values are taken from Census data except the quantity for wood preservatives, which is taken from the survey.

[c] For wood preservatives the quantity is taken from the survey, but the price is taken from the Census data.

Sources: U.S. Department of Commerce. Current Industrial Reports: Paints and Allied Products, 1991. Washington, DC, Government Printing Office. 1992.

Industry Insights. Architectural and Industrial Maintenance Surface Coatings VOC Emissions Inventory Survey. Prepared for the National Paint and Coatings Association in cooperation with the AIM Regulatory Negotiation Industry Caucus. Final Draft Report. 1993.

TABLE 2-4. BEST-RESPONSE OPTION ANALYSIS—SURVEY POPULATION: FEE = $2,200/TON ($1991)

	Number[a] of Products Above the Limit	Product Quantity (L)	Reformulation Cost	Fee Payments	Foregone Profits	Total Costs	Cost Savings from Not Reformulating[b]
Reformulation selected	697	239,183,643	$10,160,142	$0	$0	$10,160,142	$0
Fee selected	409	38,235,442	$0	$3,225,366	$0	$3,225,366	$2,738,616
Withdrawal selected	46	772,807	$0	$0	$415,178	$415,178	$255,042
Total	1,153	278,191,893	$10,160,142	$3,225,366	$415,178	$13,800,686	$2,993,658

[a] Total products over-limit times (2/3)

[b] If fee not selected, reformulation costs for the 409 products that selected the fee are $5,963,982. If withdrawal is not selected, reformulation costs for the 46 products that selected withdrawal are $670,220.

Source: Industry Insights. Architectural and Industrial Maintenance Surface Coatings VOC Emissions Inventory Survey. Prepared for the National Paint and Coatings Association in cooperation with the AIM Regulatory Negotiation Industry Caucus. Final Draft Report. 1993.

1,153 products facing the reformulation versus fee decision.[e] However, these products only account for 38 million liters of output, about 14 percent of the volume subject to the decision, reinforcing the notion that the fee is selected for lower-volume products. The total fee payment for those products is about $3.7 million (average is $0.08/L), but the estimated avoided reformulation cost for the 409 products choosing the fee is over $5.9 million for a net aggregate savings to producers of about $2.7 million. Moreover, because the fee payment is simply a transfer from one sector of society (architectural coatings producers) to another (the government), the social cost savings due to incorporating the fee are the full $5.96 million reformulation cost savings, less any costs of administering the fee.

Table 2-4 indicates that 46 products elect withdrawal as the best response strategy to the regulation, which is less than 0.1 percent of the 4,846 products surveyed. The estimated foregone profits for those products total approximately $415,000, which should be considered a component of "compliance cost" of the regulation. However, this produces a $255,000 savings to society over the reformulation-only option.

All told, allowing for options other than reformulation substantially reduces compliance costs for the survey population. The option to pay the fee or to withdraw reduces the compliance cost estimate by about $3.0 million, or about 18 percent of the costs that would be incurred by the survey population if reformulation were the only compliance option.

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[e]Note that 1,153 products represent two-thirds of the total number exceeding the limits because the other one-third were assumed to reformulate without incurring the "major" reformulation cost.

2.3.5 Tonnage Exemption

All producers will be allowed to exempt the following quantity of VOC emissions from control that is phased in over three years:

Period 1: 23 Mg (25 tons)
Period 2: 18 Mg (20 tons)
Period 3: 9 Mg (10 tons)

Because these represent relatively small volumes, especially after the 3-year phase-in, the tonnage exemption will likely serve in lieu of the exceedance fee for small volume products and thereby reduce fee payments by producers employing the tonnage exemption.

To the extent that the tonnage exemption replaces the fee as a compliance option for some products, the foregone fee payments represent the reduced impact on producers. Consider the post-year 3 case where 9 Mg of VOC emissions are exempted from control. Suppose that 3.6 Mg of these emissions are "exceedance" emissions (i.e., emissions above the amount allowed in the VOC content standards). If a fee were assessed to these emissions, the cost to the firm would be 3.6 • \$2,200 = \$7,920 (\$1991). Therefore, the exemption allows the firm to avoid this impact. Note that while this reduces the private impact on firms subject to the exemption/fee, there is no corresponding effect on the social cost of the regulation as the reduced fee payments are just reduced transfers from one party (producers) to another party (government).

2.4 COST ANALYSIS UNCERTAINTIES

Table 2-5 lists the key assumptions and main areas of uncertainty surrounding the cost estimates. Items of

TABLE 2-5. REFORMULATION COST ANALYSIS UNCERTAINTIES

Assumptions

- Initial reformulation cost is $87,000.
- Useful life of reformulation is (1) 8 years, (2) forever.
- Discount rate is 7 percent.

Potential upward bias factors

- Effects of tonnage exemption not considered.
- Costs assumed constant in the future; but may fall over time as new technology is developed and disseminated.
- Industry trends since 1991 have moved toward lower VOC formulations.
- Costs may be borne partly by material suppliers.
- Regulatory baseline is changing. State regulations have been implemented (e.g., Massachusetts), and some producers have already developed formulations and incurred reformulation costs to comply with new as well as existing regulations. These formulas can be applied to a federal rule at a minimal cost.

Potential downward bias factors

- Costs are confined to the reformulated product itself; users may incur additional costs to adapt application systems.
- Multiple products may be lumped together as one in the survey. Therefore, multiple reformulations may be necessary in some cases where a single reformulation is projected.

Potential factors with unknown directional effects

- Estimate is for a “typical” product; individual products may differ.
- Lower-bound estimate of 8 years for useful life of reformulation is speculative.
- Reformulation may positively or negatively affect variable production costs (e.g., materials).
- Effects on product quality and performance are unknown; anecdotal evidence shows both positive and negative effects depending on the product.
- Costs may rise/fall based on amount of “excess VOC” to reduce.
- The number of reformulations for nonsurveyed products may be mis-estimated due to lack of data.

uncertainties are grouped by the likely direction of bias on the cost estimate: upward, downward, or unknown.

2.4.1 Upward Bias

As indicated in the previous section, one source of upward bias in the cost estimates is that the analysis does not directly account for the effect that the tonnage exemption would have on cost mitigation.

The analysis may overstate reformulation costs incurred by architectural producers by not explicitly accounting for cost-saving technological innovation. Spillover effects from early reformulation efforts could substantially reduce the costs for other formulas. This may be facilitated by the role that material suppliers play in developing formulas, particularly in the case of smaller architectural coatings manufacturers. Economies of scale may occur because material suppliers solve the problem for multiple clients and formulas.

Since this rule was initially proposed, for example, Massachusetts has implemented its own regulation for architectural coatings. In compliance with that regulation, 104 companies have registered compliant architectural coatings with the Massachusetts Department of Environmental Protection.[60] Many of those companies operate on a national scale. Therefore, products those companies make that currently meet the Massachusetts regulation do not need to be further reformulated to comply with the national rule. Those costs are not "backed-out" in this analysis, which imparts an upward bias of unknown magnitude on the costs presented.

2.4.2 Downward Bias

A couple of factors may lead to an understatement of the reformulation costs presented here. First, by focusing on costs to the coatings manufacturer, the current analysis does not account for any fixed costs that coating users may bear as they switch to compliant formulas. Based on public comments, the item of greatest concern in this category is application equipment for traffic marking coatings. These costs are now explicitly addressed in a separate section of this report and included in the final cost-effectiveness analysis below.

The second item that may cause downward bias in the cost estimates relates to the definition of products in the survey data. The analysis treats each survey entry as a separate product and assigns each noncompliant entry a single reformulation. If, instead, survey respondents combined several products requiring several reformulations into one survey entry, total reformulation costs for the survey population would be underestimated. It is impossible to determine whether this is a systematic problem with the survey data and, if so, the extent to which it biases the current estimate.

While the reformulation cost estimate is the main source of uncertainty in the analysis, another item that bears mentioning relates to the selection of nonreformulation response options (fee or withdrawal). The analysis assumes that producers will select the lower-cost option (reformulation or the fee) and exit if the lower-cost option exceeds the value of the profit stream. However, some rigidities (e.g., shortage of scientist hours for new formula development) might make reformulation difficult in the very short run. However, the phased tonnage exemption period mentioned above should provide some relief in overcoming the short-run rigidity particularly for smaller producers.

2.4.3 Unknown Directional Effects

Several items that have unknown directional effects on the cost estimates are listed in Table 2-9. Of particular relevance is the absence of variable production cost effects, notably the difference in material costs. The EPA was unable to obtain verifiable information on material cost effects of reformulation. Anecdotally, it was suggested that solventborne material costs might rise in some situations (e.g., those described in the comment) but might fall in others (e.g., substitution of water carriers for solvent). The net effect across all products is unknown. Without any hard data on the size or direction of material cost effects, the EPA assumed no net material cost effects in the analysis.

The compliance strategy decision is likely to be complicated by issues other than cost that relate to the profitability of reformulation. If a product serves a narrow market niche, reformulation may fundamentally alter the product’s attributes and erode the niche position. In such a case, the producer may find that choosing reformulation is not profitable. Although concerns regarding the regulation’s constraints on product differentiability are undoubtedly real in some cases, this complexity is not explicitly addressed in the quantitative analysis, primarily because of the difficulty in observing both levels of and changes in product quality.

51. AIM Coatings Regulatory Negotiation Committee meeting. July 28-30, 1993, Washington, DC. Meeting Summary.

52. Ref. 51.

53. Office of Management and Budget. Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs. Memorandum for Heads of Executive Departments and Establishments. Circular No. A-94 Revised (Transmittal Memo No. 64). October 29, 1992.

54. ICF Consulting Associates, Incorporated. Small Business Economic Impact Study. Prepared for the South Coast Air Quality Management District. Final Report. June 17, 1988.

55. Ref. 2.

56. Ref. 2.

57. Telecon between Chris Sarsony, Eastern Research Group to Brian Murray, Research Triangle Institute, December 15 1997.

58. U.S. Department of Commerce. 1991 Annual Survey of Manufactures: Statistics for Industry Groups and Industries. Washington, DC, Government Printing Office. 1992.

59. Ref. 2.

60. Memorandum. Seagroves, Monica, Eastern Research Group, to Ducey, Ellen, U.S. Environmental Protection Agency. January 7, 1998. Architectural coatings certification and registration information from Massachusetts Department of Environmental Protection.